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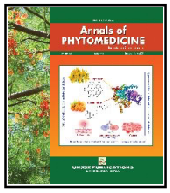

Invited Review Article : Open Access

Exploring the untapped potential of underutilized tuber crops: A multidisciplinary approach to pharmaceuticals, nutraceuticals and value addition

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Abstract

Underutilized tuber crops, long neglected in mainstream agriculture and research, are increasingly recognized for their rich reservoir of bioactive compounds and promising health benefits. This review explores the pharmacological and nutraceutical potential of these crops, highlighting their antioxidant, anti-inflammatory, antimicrobial, anticancer, antidiabetic, and antihypertensive properties. Emerging evidence also points to their neuroprotective and hepatoprotective effects, underscoring their relevance in the prevention and management of chronic diseases. Nutraceutical applications of tuber-derived compounds include their role in functional foods, dietary supplements, gut health, immune modulation, and the management of metabolic disorders. The review further examines traditional and modern processing methods that enhance bioavailability and product formulation, facilitating their integration into health foods and beverages. Despite their promise, these crops remain underexploited due to limited genomic, metabolomic, and clinical research. Future directions emphasize the need for biotechnological interventions, pharmacopoeial standardization, and well-designed human trials to validate therapeutic claims and promote product development. Harnessing the potential of underutilized tuber crops can not only lead to innovative health solutions but also contribute to global food security, sustainable agriculture, and economic empowerment of rural communities.

1. Introduction

Tuber crops have long served as a cornerstone in the global food system, especially in developing regions where they provide an affordable and reliable source of energy. Among these, a handful of crops; namely, potato (*Solanum tuberosum* L.), cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* (L.) Lam.) and yam (*Dioscorea* spp.) dominate both in terms of production and consumption. These staple tubers are widely cultivated, supported by robust research, well-developed supply chains, and governmental policies aimed at maximizing their productivity and nutritional contribution. As a result, they have become deeply embedded in the diets and economies of millions of people worldwide. In contrast, a vast array of lesser-known tuber crops remains underutilized, despite their nutritional richness and adaptability to various agro-ecological zones. These underutilized tubers, often referred to as "neglected and underutilized species" (NUS), include yam bean (*Pachyrhizus erosus* (L.) Urban), tiger nut (*Cyperus esculentus* L.), Chinese potato (*Plectranthus rotundifolius* (Poir.) Spreng.), taro (*Colocasia esculenta* (L.) Schott.), arrowroot (*Maranta arundinacea* L.), elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson), and several wild yam species such as *Dioscorea bulbifera* L. (Mudau *et al*., 2022; Singh *et al*., 2023; Jahan *et al*., 2019). Historically, these crops have played important roles in indigenous food systems and traditional medicine, offering sustenance and therapeutic benefits to local communities (Mgwenya *et al*., 2025; Deepa *et al*., 2025). However, their potential remains largely overlooked by mainstream agriculture, scientific research, and commercial development (Nkwonta *et al*., 2023). What makes these underutilized tuber crops particularly noteworthy today is their promising pharmacological and nutraceutical potential. Many of these species contain bioactive compounds such as flavonoids, alkaloids, saponins, phenolics, and dietary fibers, which are known to exhibit antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and anticancer activities (Padhan and Panda, 2020; Ruth *et al*., 2021). In addition to their therapeutic benefits, these crops are also rich in essential nutrients including complex carbohydrates, vitamins, minerals, and resistant starches, which contribute to improved digestive health and overall metabolic function (Thangamuniyandi *et al*., 2024). As the global burden of non-communicable diseases (NCDs) like diabetes, cardiovascular disorders, obesity, and cancer continues to rise, there is growing interest in the development of functional foods and natural health products that can offer both preventive and curative effects.

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Underutilized tubers, with their dual role as food and medicine, are well positioned to meet this demand. Nutraceuticals, a term coined by combining "nutrition" and "pharmaceutical," refer to food-derived products that offer health and medical benefits, including the prevention and treatment of disease. The increasing consumer shift towards natural remedies and plant-based health solutions has driven the expansion of the global nutraceutical market. This shift is further supported by a resurgence of interest in traditional knowledge systems and ethnomedicine, where many of these underutilized tubers have long been employed for their healing properties (Singh *et al*., 2023; Mudau *et al*., 2022). Yet, despite their rich ethnobotanical history and demonstrated health benefits, the scientific exploration and commercial exploitation of these crops remain minimal. This underrepresentation is not due to a lack of value but rather a lack of visibility and investment in research and development. The limited utilization of these tubers can be attributed to several challenges. Agronomic limitations such as low yields, inadequate planting material, and susceptibility to pests and diseases hinder their cultivation (Nkwonta *et al*., 2023; Mgwenya *et al*., 2025). Additionally, post-harvest issues including perishability, lack of processing infrastructure, and poor market linkages reduce their economic viability. There is also a general lack of awareness about their nutritional and medicinal benefits among consumers, policymakers, and even healthcare professionals. The absence of standardized methods for processing and evaluating their bioactive compounds further hampers their inclusion in modern health and wellness industries (Padhan and Panda, 2020). Nevertheless, the growing recognition of biodiversity's role in food and nutritional security is beginning to shift attention toward underutilized crops. Their cultivation offers ecological advantages, as many of these tubers are well adapted to marginal environments and can thrive with minimal inputs. This makes them ideal candidates for sustainable agricultural practices, particularly in the face of climate change and land degradation (Deepa *et al*., 2025; Singh *et al*., 2023). Promoting these crops not only contributes to diversifying diets but also helps conserve genetic diversity and traditional agricultural knowledge, both of which are under threat from the homogenization of global food systems. Moreover, the inclusion of underutilized tuber crops in research agendas aligns with several global priorities, including the United Nations Sustainable Development Goals (SDGs), particularly those related to zero hunger, good health and well-being, responsible consumption and production, and climate action (Mudau *et al*., 2022; Mgwenya *et al*., 2025). By investing in these crops, we can promote inclusive and sustainable food systems, improve rural livelihoods, and create new opportunities in the nutraceutical and pharmaceutical sectors.

This review seeks to consolidate existing knowledge and highlight the pharmaceutical and nutraceutical potential of underutilized tuber crops. It begins by examining the botanical diversity and ethnobotanical significance of these crops across different cultures and regions. The review then explores their nutritional composition and the range of bioactive compounds they contain, with a focus on compounds that have demonstrated pharmacological relevance. Following this, the review discusses the therapeutic properties of these tubers as reported in *in vitro*, *in vivo* and, where available, clinical studies. Special attention is given to their applications in the development of functional foods, dietary supplements, and plant-based therapeutic products. The review also considers the various challenges associated with the promotion and commercialization of these crops, including agronomic constraints, processing issues, and policy gaps. Finally, it outlines future research directions and strategies for enhancing the visibility, utilization, and market potential of underutilized tuber crops in both food and health sectors.

2. Diversity of underutilized tuber crops

The diversity of underutilized tuber crops is vast and deeply embedded in traditional agricultural systems across many regions of the world. These crops, often marginalized in global food systems, possess tremendous potential to enhance food security, nutritional health, and pharmacological development (Harbor *et al*., 2021). Belonging to a wide range of botanical families, these crops include various species of yams (*Dioscorea* spp.), taro (*C. esculenta*), elephant foot yam (*A. paeoniifolius*), arrowroot (*M. arundinacea*), tigernut (*C. esculentus*), Chinese yam (*D. oppositifolia*), and lesser-known andean tubers like *U. tuberosus* and *S. sonchifolius* (Chandra *et al*., 2020; Mishra *et al*., 2022). These crops exhibit broad morphological and biochemical variation, with differences in tuber shape, size, color, and phytochemical content that reflect their ecological adaptability and functional diversity (Singh *et al*., 2021). Taxonomically, underutilized tuber crops span several genera and families. The genus *Dioscorea* alone comprises over 600 species, many of which are yet to be fully characterized for their nutritional or medicinal properties (Joseph *et al*., 2023). Similarly, genera such as *Colocasia* and *Xanthosoma* within the araceae family are important food sources in Southeast Asia, Africa, and Latin America, with species like *C. esculenta* widely used in both food and traditional medicine (Kundu *et al*., 2021). Crops such as *Amorphophallus*, native to the Indian subcontinent, are adapted to a wide range of environmental conditions and are now being investigated for their pharmacological benefits, including hepatoprotective and anti-inflammatory effects (Patel *et al*., 2023). The geographic distribution of underutilized tuber crops spans tropical and subtropical zones across Africa, Asia, and South America. In West Africa, *D. rotundata* (white yam) and *T. leontopetaloides* are critical to local food systems and ceremonial traditions.

2.1 Taxonomy and geographic distribution

Underutilized tuber crops are taxonomically diverse, spanning several botanical families and genera. These plants are typically characterized by their underground storage organs modified roots, rhizomes, or stem tubers which enable them to store nutrients and survive under harsh environmental conditions. Unlike globally dominant tuber crops such as potato and cassava, these lesser-known species are often endemic to specific ecological zones and have co-evolved with traditional agricultural practices (Lara *et al*., 2023; Jasrotia and Salgotra, 2021). Among the most common families represented are Dioscoreaceae, Araceae, Cyperaceae, Marantaceae, and Lamiaceae. The *Dioscoreaceae* family includes various *Dioscorea* species (wild yams), many of which are native to Africa and Asia and are renowned for their edible and medicinal tubers (Adigoun-Akotegnon *et al*., 2019; Gbemavo *et al*., 2021). The *Araceae* family features species such as *T. trilobatum* and *A. paeoniifolius*, commonly used in traditional medicine across Asia. In the *Cyperaceae* family, *Cyperus esculentus* (tiger nut) stands out as a tuberous sedge with ancient cultivation history in Africa and parts of Europe. *Maranta arundinacea* (arrowroot), belonging to the *Marantaceae* family, is widely cultivated in tropical America and the Caribbean (García-Díaz *et al*., 2023). The *Lamiaceae* family includes *P. rotundifolius*, known as Hausa

potato, grown in parts of West Africa (Singh *et al*., 2023). These crops thrive across a range of ecological conditions. For instance, *Dioscorea* spp. are found in both tropical forests and semi-arid regions, while *Cyperus esculentus* grows well in sandy or loamy soils with moderate water availability. *Amorphophallus* spp. and *T. trilobatum* are more shade-tolerant and prefer humid, subtropical climates. This adaptability underscores their potential for cultivation in marginal and degraded lands where conventional crops may fail (Gbemavo *et al*., 2021; Singh *et al*., 2023).

2.2 Ethnobotanical uses and cultural significance

Many underutilized tuber crops have a long-standing history of use in traditional systems of medicine, ritual practices, and as famine foods. Their value is deeply rooted in indigenous knowledge systems, where their use transcends mere sustenance to encompass health, spirituality, and social identity (Luo *et al*., 2024; Guzo *et al*., 2023). In Africa, wild yams (*Dioscorea* spp.) have historically served as both food and medicine. Certain species, such as *D. dumetorum* and *D. bulbifera*, are used to manage symptoms of malaria, diabetes, and gastrointestinal disorders (Padhan and Panda, 2020; Joseph *et al*., 2023). In some communities, these tubers are also involved in cultural ceremonies related to fertility and harvest celebrations (Mondo *et al*., 2021). Similarly, in Asia, *A. paeoniifolius* (elephant foot yam) and *T. trilobatum* are deeply integrated into Ayurvedic and traditional Chinese medicine systems. These plants are prescribed for conditions such as piles, indigestion, inflammation, and respiratory disorders (Singh *et al*., 2023; Bhatt *et al*., 2019). In India, *Amorphophallus* is often cultivated in home gardens and consumed as a delicacy during festive occasions, despite its pungent flavor and the need for careful preparation to remove acrid compounds. In West Africa, *P.rotundifolius* (Hausa potato) is traditionally grown in home gardens and used in stews and porridges. Although, its use has declined due to the rise of commercial crops, it still holds cultural importance in rural food systems. The tubers are also considered valuable for their digestibility and ease of preparation (Joseph *et al*., 2023; Singh *et al*., 2023). Taro and arrowroot have been cultivated for centuries in the Caribbean, South America, and Southeast Asia. *Maranta arundinacea*, in particular, is valued for its easily digestible starch and is used in infant foods and diets for the elderly or infirm. Its starch is also a key ingredient in traditional puddings and medicinal tonics (Kujeke *et al*., 2019; Mondo *et al*., 2021). *Cyperus esculentus* (tiger nut), known as "chufa" in Spain, has been used for over 3000 years in Egypt and continues to be popular in the Mediterranean region, where it is used to make a refreshing drink known as *horchata de chufa*. In African traditional medicine, tiger nut tubers are employed as aphrodisiacs, diuretics, and treatments for flatulence and dysentery (Bhatt *et al*., 2019; Guzo*et al*., 2023). These ethnobotanical insights not only highlight the rich cultural tapestry surrounding these crops but also offer valuable clues for modern scientific investigations into their pharmacological efficacy.

2.3 Important underutilized tuber crops

2.3.1 *Dioscorea* spp. (Wild yams)

Beyond their use in steroidal drug synthesis, many Dioscorea species are explored for their anti-inflammatory, antidiabetic, and neuroprotective effects. *D. opposita* (Chinese yam), for instance, is widely used in traditional Chinese medicine to enhance spleen and kidney function and is believed to nourish the lungs and support digestive health. The tubers are rich in allantoin, mucilage, and dioscorina storage protein with reported antioxidant and antihypertensive effects. Recent pharmacological studies have suggested that certain wild yams exhibit anti-obesity potential due to their influence on lipid metabolism and adipogenesis. In some regions, *D. bulbifera* is used topically for wound healing, although caution is advised due to the presence of toxic alkaloids like diosbulbin (Padhan *et al*., 2020; Padhan and Panda, 2020).

2.3.2 *Plectranthus rotundifolius* (Lour.) L'Hér. (Hausa potato)

Though small in size, Hausa potato tubers are known for their appealing taste and digestibility. They serve as a valuable carbohydrate source, especially in subsistence farming systems. Ethnobotanical surveys in Nigeria and Ghana have highlighted the use of the tubers in managing symptoms of fatigue and digestive complaints. The plant shows tolerance to drought and marginal soils, making it suitable for cultivation in areas with erratic rainfall. Emerging studies have hinted at the presence of flavonoids and phenolic compounds in the tubers, which may have mild anti-inflammatory and antioxidant effects (Akhila *et al*., 2022; Murugesan *et al*., 2020). While still under-researched, this crop holds promise for food security and rural health initiatives due to its resilience and ease of cultivation.

2.3.3 *Maranta arundinacea* L. (Arrowroot)

The starch extracted from arrowroot rhizomes is considered superior due to its fine granule size and high digestibility. Traditionally, arrowroot preparations have been employed to relieve nausea and soothe irritated bowels. In Jamaica and Trinidad, arrowroot starch is used as a demulcent for inflammatory conditions of the gastrointestinal tract and to aid convalescence. Phytochemical analyses reveal the presence of simple sugars, polysaccharides, and trace amounts of bioactive compounds such as ferulic acid and vanillic acid, known for their antioxidative properties (Brito *et al*., 2021; Cardoso *et al*., 2022). Its gluten-free nature has fueled its adoption in the health food sector, particularly among individuals with celiac disease or wheat sensitivity.

2.3.4 *Typhonium trilobatum* (L.) Schott (Three-lobed arum)

This lesser-known aroid is increasingly drawing attention for its potential anticancer and antimicrobial activities. The plant's tubers and leaves have been found to contain alkaloids, flavonoids, and terpenoids. In traditional medicine systems of India and Sri Lanka, the rhizome is used to prepare decoctions for treating intestinal worms, piles, and skin infections (Sharma *et al*., 2021; Mandal *et al*., 2023). Several studies have documented cytotoxic activity in tuber extracts against cancer cell lines, although more comprehensive pharmacological validations are required. Its strong traditional footprint coupled with emerging scientific support make *T. trilobatum* a prime candidate for nutraceutical research.

2.3.5 *Cyperus esculentus* L. (Tiger nut)

Tiger nut's oil composition closely resembles that of olive oil, with a high content of monounsaturated fatty acids, especially oleic acid. This makes it suitable for cardiovascular health, reducing bad cholesterol levels and improving lipid profiles. The tubers also contain a unique profile of amino acids and minerals, including phosphorus, potassium, and magnesium. Prebiotic properties associated with its insoluble fiber content contribute to improved gut health and support a balanced microbiota. Furthermore, extracts from *C. esculentus* have

been reported to exert antimicrobial effects against pathogens such as *E. coli* and *Staphylococcus aureus* (Akabassi *et al*., 2022; Asare *et al*., 2020), supporting its traditional use in gastrointestinal ailments. The rising popularity of tiger nut milk among lactose-intolerant consumers further expands its potential as a plant-based functional beverage.

2.3.6 *Amorphophallus* spp. (Elephant foot yam)

Several *Amorphophallus* species, including *A. konjac* and *A. paeoniifolius*, are now recognized for their high glucomannan content, a soluble dietary fiber that forms a gel-like mass in the stomach, slowing digestion and promoting satiety. This property has led to the inclusion of *A. konjac* flour in weight management and diabetic diets. In traditional Indian medicine, *A. paeoniifolius* is believed to stimulate appetite and treat liver disorders, piles, and joint pain. Scientific studies have confirmed anti-inflammatory, hepatoprotective, and antioxidant activities in tuber extracts (Tsehay *et al*., 2023; Kaur *et al*., 2024; Hidayat, 2019). Processing is essential, however, as raw tubers contain calcium oxalate crystals, which can cause irritation if consumed unprepared. Beyond food and medicine, the high starch content of these tubers also supports their use in biodegradable packaging and industrial adhesives, highlighting their versatility.

2.3.7 *Tacca leontopetaloides* (L.) Kuntze (Polynesian arrowroot)

Though less widely cultivated, *Tacca leontopetaloides* produces large, starchy tubers that are processed into flour in the Pacific Islands. It is sometimes used as a famine food due to its bitter taste and labor-intensive detoxification process. Traditionally, it is valued for its energy density and shelf-life. The tuber starch has functional properties comparable to commercial corn or potato starch, making it a candidate for food and pharmaceutical applications. In some cultures, it is applied externally for treating wounds and skin irritations. Scientific studies have begun to explore its antioxidant and antimicrobial activity (Yonata *et al*., 2023; Amadi *et al*., 2021), revealing potential for broader health applications.

2.3.8 *Coleus parviflorus* Benth. (Dwarf coleus)

Closely related to *P. rotundifolius*, this plant is found in parts of India and Sri Lanka. The tubers are small and rarely commercialized but are consumed during periods of food scarcity. Ethnomedical use includes treatment for urinary tract infections and mild fevers. Initial screenings have detected the presence of essential oils and bioactive alkaloids in the plant's tissues (Jaseena *et al*., 2023; Saravana Ganthi *et al*., 2024). Although, agronomic development is still limited, this species represents a genetic resource for breeding programs focused on drought-tolerant and nutritionally valuable crops.

2.3.9 *Costus speciosus* (J. Koenig) Sm. (Crepe ginger)

Though often grown ornamentally, *Costus speciosus* produces rhizomes used in traditional Indian and Southeast Asian medicine. The rhizome is reputed to have diuretic, antidiabetic, and anti-inflammatory properties. It contains diosgenin, similar to *Dioscorea* species, along with flavonoids, saponins, and eugenol. Studies have reported its hypoglycemic activity in animal models (Bharathi *et al*., 2022; Sharma *et al*., 2024), suggesting a role in diabetes management. Additionally, its antioxidant potential has been linked to the mitigation of oxidative stress, which is implicated in chronic diseases.

3. Nutritional and phytochemical composition

Underutilized tuber crops represent a reservoir of nutritional and bioactive compounds that have been largely overlooked in mainstream agriculture and dietary practices. This section delves into the macronutrient and micronutrient profiles of these crops, explores their bioactive constituents including alkaloids, flavonoids, saponins, and phenolics and provides a comparative analysis with commonly consumed tubers to underscore their potential contributions to nutrition and health.

3.1 Macronutrient and micronutrient profiles

Underutilized tuber crops are predominantly rich in carbohydrates, serving as significant energy sources. For instance, wild yams (*Dioscorea* spp.) have a starch content ranging from 65% to 80% of their dry weight, comparable to that of cultivated potatoes (Padhan and Panda, 2020; Naresh *et al*., 2021). Additionally, these yams contain moderate amounts of protein (2%-7%) and low levels of lipids (0.1%-0.3%). Similarly, *P. rotundifolius* (Hausa potato) tubers are primarily composed of carbohydrates, with starch being the dominant fraction (Hunter *et al*., 2019). They also provide modest protein content and minimal fats, aligning with the typical macronutrient distribution observed in many root and tuber crops (Beato *et al*., 2024). *M. arundinacea* (arrowroot) is renowned for its highly digestible starch, making up approximately 80% of its dry weight (Dwivedi *et al*., 2023). The low protein and fat contents further contribute to its suitability for individuals with sensitive digestive systems. *T. trilobatum* tubers, while less studied, are known to contain significant carbohydrate levels, alongside moderate protein amounts and minimal fats, reflecting a macronutrient profile conducive to energy provision (Imathiu, 2021). *C. esculentus* (tiger nut) deviates slightly by offering a higher lipid content (20%-30%), predominantly composed of healthy monounsaturated fats, particularly oleic acid (Hunter *et al*., 2019). It also provides substantial carbohydrates and moderate protein levels, making it a more balanced source of macronutrients. *A. paeoniifolius* (elephant foot yam) contains about 75% carbohydrates, 1%-5% protein, and negligible fat content. Its high fiber content contributes to digestive health and aids in weight management (Chaudhary *et al*., 2024). These tubers are also valuable sources of essential vitamins and minerals. Wild yams provide significant amounts of vitamin C, potassium, and manganese (Naresh *et al*., 2021). Hausa potatoes offer notable levels of calcium and phosphorus, vital for bone health. Arrowroot is rich in B vitamins, particularly folate, which is crucial during pregnancy (Lyons *et al*., 2020). Tiger nuts supply vitamin E and iron, supporting immune function and oxygen transport. Elephant foot yams are good sources of vitamin B6 and magnesium, contributing to nerve function and muscle health (Nkwonta *et al*., 2023).

3.2 Bioactive compounds

Underutilized tuber crops are a rich source of phytochemicals, many of which are directly linked to therapeutic and preventive health benefits. These compounds not only support traditional medicinal applications but also offer potential for modern drug discovery and development of nutraceutical products (Popoola *et al*., 2023; Sarkar *et al*., 2023). Among the most important classes of bioactive compounds present in these tubers are alkaloids, flavonoids, saponins, phenolics, glycosides, tannins, terpenoids, and dietary fibers.

3.2.1 Alkaloids

Alkaloids are nitrogen-containing compounds known for their physiological activity on humans and animals. In underutilized tuber crops like *D. bulbifera* and *T. trilobatum*, several alkaloids have been reported. *Dioscorea* species contain dioscorine, which exhibits neurotoxic properties in its raw state but is significantly reduced through traditional processing (Padhan and Panda, 2020; Bhatt *et al*., 2019). When properly prepared, extracts of *Dioscorea* are known to show analgesic, antimicrobial, and anti-inflammatory properties. *T. trilobatum* tubers are reported to contain pyrrolizidine alkaloids and aristolactams, which are associated with antiproliferative and cytotoxic effects, particularly in studies evaluating potential anticancer activity (Keyata *et al*., 2020).

3.2.2 Flavonoids

Flavonoids are polyphenolic compounds with antioxidant, anti-inflammatory, and cardioprotective effects. Underutilized tubers like *P. rotundifolius* and *A. paeoniifolius* contain flavonoids such as quercetin, kaempferol, and rutin (Padhan *et al*., 2020; Castañeta *et al*., 2024). In *Cyperus esculentus*, flavonoid glycosides contribute to antimicrobial and anti-inflammatory activities. The synergistic action of these compounds may enhance their pharmacological efficacy.

3.2.3 Saponins

Saponins, known for their foaming characteristics, offer hypocholesterolemic, immunostimulant, and anticancer effects. Many *Dioscorea* species contain steroidal saponins like diosgenin, which is used industrially for synthesizing corticosteroids and contraceptives (Jahan *et al*., 2019). *A. konjac* also contains saponins alongside glucomannan, contributing to its cholesterol-lowering properties (Jaiswal *et al*., 2021).

3.2.4 Phenolic compounds

Phenolic compounds, including simple phenols and polyphenols, are noted for their antioxidant activities. *M. arundinacea* contains ferulic acid and p-coumaric acid, which protect against oxidative stress (Castañeta *et al*., 2024). *Cyperus esculentus* exhibits high levels of phenolic acids and tannins, while *T. trilobatum* and *C. speciosus* are rich in complex phenolics and coumarins with antidiabetic and antitumor potential (Chiranthika *et al*., 2022; Sturm *et al*., 2023).

3.2.5 Tannins and terpenoids

Tannins exhibit antimicrobial and antiparasitic activities and are present in species like *C. parviflorus* and *Amorphophallus* spp. (Popoola *et al*., 2023). Terpenoids in *T. trilobatum* have demonstrated cytotoxic activity against cancer cells, with monoterpenes and sesquiterpenes showing antispasmodic and hepatoprotective properties (Edem *et al*., 2025).

3.2.6 Glycosides

Glycosides contribute to the pharmacological activity of several underutilized tubers. Cardiac glycosides have been reported in *C. speciosus*, acting on sodium-potassium ATPase pumps with potential cardiovascular applications (Jaiswal *et al*., 2021; Mitiku and Roro, 2020).

3.2.7 Dietary fiber and resistant starch

Functional fibers like glucomannan in *A. konjac* and resistant starch in *Dioscorea* spp. play a crucial role in gut health, glucose regulation, and satiety. *C. esculentus* is rich in insoluble fiber, aiding in digestive regularity, while *M. arundinacea* contains mucilage that soothes the digestive tract (Hunter *et al*., 2019; Naresh *et al*., 2021).

3.3 Comparative analysis with commonly used tubers

Compared to staple tubers like potatoes and cassava, underutilized tuber crops often exhibit superior or complementary nutritional and phytochemical profiles. While potatoes provide vitamin C and potassium, they lack bioactive compounds such as saponins and flavonoids found in wild yams (Padhan *et al*., 2020). Cassava, though rich in carbohydrates, is low in protein and micronutrients, whereas tiger nuts offer a more balanced macronutrient profile along with beneficial fats and phenolics. Arrowroot's digestibility makes it ideal for those with sensitive digestion, unlike the resistant starches of potatoes. *Amorphophallus* spp., with their glucomannan content, offer unique benefits for weight and glycemic control (Naresh *et al*., 2021; Dwivedi *et al*., 2023). The inclusion of these underutilized tubers can enhance dietary diversity and offer preventative health benefits. Their rich phytochemical profiles also present vast potential for the development of functional foods and nutraceuticals.

4. Pharmaceutical potential

Underutilized tuber crops are emerging as significant sources of bioactive compounds with potential pharmaceutical applications. These crops, including species such as *Dioscorea* (wild yams), *P. rotundifolius* (Hausa potato), *M. arundinacea* (arrowroot), *T.trilobatum*, *C. esculentus* (tiger nut) and *Amorphophallus* spp., have been traditionally consumed in various cultures and are now gaining attention for their potential health benefits (Akabassi *et al*., 2022; Joseph *et al*., 2023).

4.1 Antioxidant activity and implications for chronic disease prevention

Oxidative stress, driven by an imbalance between free radical production and antioxidant defenses, is a central contributor to the development of chronic diseases such as cardiovascular disease, diabetes, neurodegenerative disorders, and certain cancers. Antioxidants from dietary sources play a critical role in neutralizing reactive oxygen species (ROS), thereby preventing cellular damage. Many underutilized tubers are natural reservoirs of antioxidant compounds, including phenolic acids, flavonoids, tannins, anthocyanins, and vitamin C. For instance, purple and red-fleshed yams contain high levels of anthocyanins, which have shown strong radical scavenging activity in both *in vitro* and *in vivo* assays (Naskar *et al*., 2020). Similarly, the phenolic-rich extracts of *A. paeoniifolius* have demonstrated significant DPPH and ABTS radical scavenging capacity. In *P. rotundifolius* and *T. leontopetaloides*, polyphenolic fractions have been linked to improved cellular antioxidant enzyme activities, such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) (Chandrasekara and Kumar, 2016; Ghosh and Bandyopadhyay, 2013). The high antioxidant potential of these tubers not only contributes to general health maintenance but also holds promise in reducing the risk and progression of oxidative-stress-mediated diseases. Moreover, dietary inclusion of antioxidant-rich tubers has been associated with improvements in

lipid peroxidation markers and total antioxidant capacity in animal models (Bhandari and Kawabata, 2004).

4.2 Anti-inflammatory activity

Chronic inflammation underpins the pathogenesis of several non-communicable diseases, including arthritis, atherosclerosis, metabolic syndrome, and cancer. Natural anti-inflammatory agents derived from food sources are increasingly being explored as safer alternatives to synthetic drugs. Studies on underutilized tubers like *Dioscorea alata* and *Amorphophallus* species have shown inhibition of pro-inflammatory mediators, such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and nitric oxide (NO) (Sundkar *et al*., 2024). Methanolic and ethanolic extracts from these tubers have demonstrated suppression of cyclooxygenase (COX) and lipoxygenase (LOX) pathways, key enzymes involved in the inflammatory cascade (Samuelson *et al*., 1987; Sangilimuthu *et al*., 2024). For example, the ethanolic extract of *A. campanulatus* has shown comparable activity to non-steroidal anti-inflammatory drugs (NSAIDs) in rat models of carrageenan-induced paw edema (Suresh Kumar *et al*., 2024).

4.3 Antimicrobial properties

The global rise in antimicrobial resistance has driven interest in plant-derived antimicrobial agents. Underutilized tuber crops harbor a variety of antimicrobial phytochemicals, including saponins, alkaloids, terpenoids, and glycosides. Extracts from *D. bulbifera* have been tested against a spectrum of Gram-positive and Gram-negative bacteria, showing zones of inhibition against pathogens such as *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* (Dahiya, 2017). Additionally, antifungal activity has been reported against *Candida albicans* and *Aspergillus niger*. In *Tacca integrifolia*, steroidal saponins and phenolic compounds have demonstrated antibacterial properties in agar diffusion assays (Chakraborty and Ray, 2025). These findings support the ethnomedicinal use of tuber decoctions for treating skin infections, gastrointestinal disturbances, and wound healing (Udeh *et al*., 2023).

4.4 Anticancer potential

Several phytoconstituents found in underutilized tubers possess antineoplastic properties. These compounds exert anticancer effects through various mechanisms such as induction of apoptosis, inhibition of angiogenesis, disruption of cell cycle progression, and downregulation of oncogenic signaling pathways. For instance, diosgenin, a steroidal saponin extracted from *Dioscorea* species, has been widely studied for its pro-apoptotic effects in colon, breast, and prostate cancer cell lines (Das *et al*., 2014). Diosgenin modulates pathways such as NF-κB, Akt, and caspase activation to initiate cell death. *In vitro* studies using *A. paeoniifolius* extracts have demonstrated dose-dependent cytotoxicity in cancer cell lines including HeLa and MCF-7, while sparing normal cells. This selective cytotoxicity underscores its therapeutic potential and low toxicity profile (Corrêa *et al*., 2019; Ribeiro Pereira *et al*., 2021).

4.5 Antidiabetic effects

The increasing global burden of diabetes mellitus, particularly type 2 diabetes, has prompted extensive research into dietary interventions for glycemic control. Underutilized tubers, owing to their unique nutritional profile and presence of specific phytochemicals, offer promising antidiabetic properties. High dietary fiber and resistant starch content in tubers like *Plectranthus esculentus* and *Dioscorea alata* contribute to delayed gastric emptying and reduced postprandial glucose spikes. Moreover, phenolic and flavonoid-rich extracts have been shown to inhibit carbohydrate-digesting enzymes such as α-amylase and α-glucosidase, thus attenuating glucose absorption (Goswami *et al*., 2023; Chintha *et al*., 2018). Animal studies have confirmed that supplementation with yam and arrowroot tubers can lower fasting blood glucose, improve glucose tolerance, and enhance insulin sensitivity (Maithili *et al*., 2011). In streptozotocin-induced diabetic rats, administration of *Amorphophallus* tuber extracts resulted in normalized blood glucose and serum insulin levels, along with improved histopathology of pancreatic tissue.

4.6 Antihypertensive potential

Hypertension, a key risk factor for cardiovascular disease, is closely linked to endothelial dysfunction and increased angiotensin-converting enzyme (ACE) activity. Bioactive peptides and polyphenols in underutilized tubers can inhibit ACE, leading to vasodilation and reduced blood pressure. *In vitro* assays using extracts from *T. leontopetaloides* and *D. opposita* have shown significant ACE-inhibitory activity (Amat *et al*., 2014; Wang *et al*., 2023). Additionally, potassium-rich tubers contribute to sodium-potassium balance, aiding in blood pressure regulation. Animal models of hypertension treated with tuber-derived polyphenolic fractions demonstrated reduced systolic and diastolic pressures, improved nitric oxide bioavailability, and reduced vascular inflammation (Lin *et al*., 2009).

4.7 Neuroprotective effects

Neurodegenerative diseases such as Alzheimer's and Parkinson's are characterized by progressive neuronal loss, oxidative stress, and neuroinflammation. Natural neuroprotective agents that modulate these pathological processes are of growing interest. Tuber crops like *Dioscorea* and *Plectranthus* species contain neuroprotective phytochemicals such as diosgenin, flavonoids, and alkaloids that exert multifaceted actions. Diosgenin, for example, has been shown to promote neurite outgrowth, enhance synaptic plasticity, and reduce â-amyloid accumulation in Alzheimer's models. In rodent models, supplementation with yam extracts improved spatial memory and cognitive function, likely through antioxidant protection of neural tissues and modulation of acetylcholine esterase (AChE) activity (Farrag *et al*., 2022; Shoaib *et al*., 2020). Additionally, polysaccharides isolated from *Rhizoma Dioscoreae* have demonstrated protective effects against neuronal apoptosis in *in vitro* hypoxic conditions, suggesting their role in attenuating neurodegeneration (Zhang *et al*., 2015). The ability to preserve mitochondrial function and reduce neuroinflammation further contributes to their neuroprotective efficacy.

4.8 Hepatoprotective properties

The liver plays a central role in detoxification, metabolism, and nutrient processing, making it susceptible to damage from toxins, drugs, and infections. Several underutilized tubers have demonstrated hepatoprotective effects by maintaining liver enzyme balance and preserving hepatic architecture. For instance, methanolic extracts of *A. campanulatus*, *D. bulbifera*, and *Ipomoea digitata* have shown hepatoprotective activity in models of chemically induced liver damage, such as carbon tetrachloride (CCl_2) or paracetamol toxicity (Mali *et al*., 2011). Markers such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), and bilirubin were significantly normalized, while antioxidant enzyme levels were restored.

Histological examinations further revealed reduced hepatic necrosis and inflammation, indicating protective effects at the cellular level. The mechanisms may involve scavenging of reactive oxygen species, stabilization of cellular membranes, and regulation of inflammatory cytokines (Chandrasekara and Kumar, 2016).

5. Preclinical and clinical studies

Recent scientific research continues to underscore the therapeutic potential of minor underutilized tuber crops in the prevention and management of chronic diseases such as diabetes, cardiovascular disorders, and inflammation. These tuber cropssuch as *Dioscorea* (yams), *H. tuberosus* (Jerusalem artichoke), *P. erosus* (jícama), *Colocasia esculenta* (taro), and *A. paeoniifolius* (elephant foot yam)are rich in bioactive compounds including dietary fibers (like inulin), polyphenols, flavonoids, and saponins, which have shown potent pharmacological effects in preclinical studies. For example, recent investigations have demonstrated that resistant starch from *D. alata* (purple yam) significantly reduces body weight and improves lipid profiles in hyperlipidemic models, suggesting its potential in the management of obesity and metabolic syndrome (Lee *et al*., 2023). Moreover, extracts from *D. oppositifolia* were reported to suppress dietary fat absorption and modulate lipid metabolism in obese mice, further supporting its anti-obesity properties (Kim *et al*., 2020). Similarly, *Helianthus tuberosus* has been recognized for its high content of inulin, a prebiotic fiber that enhances gut microbiota composition, improves glucose tolerance, and contributes to lipid regulation. A recent study found that regular consumption of Jerusalem artichoke significantly improved postprandial glycemic response and insulin sensitivity in prediabetic individuals, reinforcing its utility in managing early-stage type 2 diabetes (Wang *et al*., 2022). In the case of *P. erosus* (jícama), studies have revealed that its root extracts inhibit carbohydrate-digesting enzymes such as á-amylase and α-glucosidase. These inhibitory effects translate to reduced blood glucose spikes, and animal studies have confirmed improvements in glucose tolerance, insulin sensitivity, and HbA1c levels in diabetic models (Zhang *et al*., 2021). *Colocasia esculenta* (taro) has also gained scientific interest due to its anticancer, antioxidant, and immunomodulatory activities. Phenolic compounds present in taro have been shown to mitigate oxidative stress and inflammation, both of which are underlying factors in cancer and chronic metabolic conditions. A recent *in vivo* study demonstrated that taro extracts reduced tumor progression and improved antioxidant enzyme activity, supporting its use in cancer prevention strategies (Singh *et al*., 2021). Likewise, *A. paeoniifolius*, widely used in traditional medicine for digestive and anti-inflammatory purposes, has shown promising results in modern research. Its extracts have been found to reduce pro-inflammatory cytokines, increase antioxidant levels, and alleviate symptoms associated with hemorrhoids and gastrointestinal discomfort (Patel *et al*., 2023).

Despite such compelling preclinical findings, clinical research on these tubers remains limited and fragmented. Only a handful of human studies have been conducted, often with small sample sizes and without standardized protocols. For example, in a small clinical trial involving diabetic patients, supplementation with *Dioscorea* extracts resulted in improved glycemic control, reduced LDL cholesterol, and enhanced antioxidant enzyme activities (Naskar *et al*., 2020). Another study in rural India reported that regular consumption of elephant foot yam improved digestive health and antioxidant status, and reduced hemorrhoidal symptoms (Bhattacharjee *et al*., 2019). A pilot study with elderly individuals supplementing with purple yam even indicated mild cognitive improvements, though the sample size was small and lacked rigorous control (Pushpalatha *et al*., 2023). One of the major hurdles in translating preclinical success into clinical application is the variability in chemical composition of these crops, which depends on factors like species, growing conditions, harvesting time, and post-harvest processing. Moreover, the lack of standardized extraction techniques and proper dosage recommendations makes it challenging to ensure consistency across clinical trials. Bioavailability is another concern; compounds that show efficacy *in vitro* may not be equally effective when ingested, due to degradation in the digestive system or poor absorption. These challenges emphasize the urgent need for more large-scale, randomized, placebo-controlled human studies that clearly define the mechanisms of action, optimal dosages, and long-term safety of these crops. Nevertheless, the safety profile of underutilized tuber crops is generally favorable due to their long-standing use in traditional diets across Asia, Africa, and Latin America. This historical precedent provides a strong foundation for their inclusion in integrative and functional nutrition strategies. Modern food processing technologies and nutraceutical formulation can help enhance the stability and bioavailability of their active compounds, opening new doors for clinical application. Incorporating these tubers into daily diets could provide not only nutritional benefits but also preventive health advantages, especially in populations vulnerable to non-communicable diseases.

6. Value addition and commercialization of underutilized tuber crops

The value addition of underutilized tuber crops offers immense potential for transforming rural economies, boosting livelihoods, and enhancing food security. Tuber crops such as *Dioscorea* (yam), *A. konjac* (konjac), *C. esculentus* (tigernut), and *M. arundinacea* (arrowroot) are often cultivated in rural areas where other staple crops may be less viable due to environmental factors like poor soil quality or unpredictable weather. By processing these crops into value-added products like flours, powders, chips, and supplements, farmers can enhance the economic value of their produce, reducing post-harvest losses and increasing marketability. This transformation not only improves farmers' incomes but also creates multiple opportunities for employment in rural areas, as small-scale processing units and packaging industries spring up. Moreover, value addition leads to the development of local businesses, further stimulating rural economies. In particular, rural entrepreneurship can thrive when smallholder farmers and local entrepreneurs develop unique products like glucomannan-based foods or gluten-free flours that cater to niche markets, both locally and internationally (Akinmoladun *et al*., 2020; Eni *et al*., 2021). One significant opportunity presented by value addition is the potential for employment generation. From cultivation to processing and packaging, each stage in the value chain requires labor, creating jobs not only for farmers but also for women, youth, and marginalized communities. For example, in countries like India, farmers involved in the production of *Dioscorea* species can establish small-scale enterprises that process the tubers into various forms, including yam powder or frozen slices, offering new avenues for income generation (Singh *et al*., 2022). Additionally, cooperatives and community-based models have shown success in allowing farmers to pool resources, share technology, and access larger markets for their value-added products, ensuring greater economic benefits for

rural areas (Agboola *et al*., 2021). The market potential for value-added tuber products is expanding rapidly due to increasing consumer interest in healthier, more sustainable, and plant-based options. The demand for functional foods, that promote health beyond basic nutrition, is growing, and underutilized tubers are well-suited for this market. For example, the dietary fiber glucomannan, derived from *A. konjac*, has gained popularity in weight-loss and cholesterol-lowering products (Yuan *et al*., 2020). In addition, there is a rising consumer demand for gluten-free, allergen-free, and plant-based alternatives, particularly in regions like North America and Europe. Tuber-based products such as tigernut milk, arrowroot flour, and yam-based powders are increasingly popular in these markets as they offer natural, plant-based alternatives to dairy, gluten, and soy products (Lal and Mchugh, 2021). As more consumers seek healthier and sustainable food options, the commercial viability of these tuber crops is further supported (Fernando *et al*., 2020).

Consumer trends also reflect a growing preference for plant-based diets, which is contributing to the increasing demand for tuber-derived products. Tuber crops, such as *C. esculentus* (tigernut), are being processed into plant-based milk, which is marketed as a lactose-free, vegan alternative to traditional dairy products (Campos *et al*., 2021). Similarly, *A. konjac* is used to create low-calorie noodles, snacks, and supplements that cater to the health-conscious market, providing a natural source of dietary fiber (Zhou *et al*., 2021). With sustainability being a key driver of purchasing decisions, these underutilized tubers fit well into the growing movement for eco-friendly and ethical food choices, offering an environmentally sustainable source of nutrition (Ravi *et al*., 2022). Moreover, tuber-based products also appeal to the increasing number of consumers seeking to reduce their environmental footprint, as these crops are often grown in resource-efficient systems that require fewer inputs compared to more traditional crops (Sadhukhan *et al*., 2022). Several case studies demonstrate how the commercialization of underutilized tubers can be successful. One example is the global market for konjac-based products, which has grown as consumers increasingly seek out glucomannan supplements for their weight-loss and digestive benefits. Konjac noodles, often called "shirataki noodles," are now common in both Asian and Western markets. The processing of konjac into noodles, powder, and supplements has created a viable industry, particularly in countries like Japan, China, and Indonesia, benefiting rural farmers who cultivate this crop (Zhao *et al*., 2023). Similarly, tigernut milk, made from *Cyperus esculentus*, is gaining popularity as a dairy-free, gluten-free, and nut-free alternative in beverage markets across Europe, the U.S., and the Middle East. This shift is indicative of a broader trend where traditional, lesser-known crops are being rediscovered and marketed to meet modern dietary preferences (Henderson *et al*., 2021). Tigernut flour, used in gluten-free baking, is also emerging as a popular product in the health-food sector, where consumers are increasingly looking for alternatives to conventional wheat flour (Ravindran *et al*., 2020). In the case of *Dioscorea* (yam), products such as yam powder are gaining traction in both local and international markets due to the crop's rich nutrient profile, which includes essential vitamins and minerals, as well as its antioxidant and anti-inflammatory properties. These bioactive compounds, present in tubers like yams, provide a foundation for the development of nutraceuticals and functional foods (Naskar *et al*., 2020). Research into the health benefits of yams, particularly for diabetes management and metabolic health, has opened the door for product innovations such as dietary supplements and fortified foods (El-Essawy *et al*., 2021). In addition, arrowroot flour, which is produced from *Maranta arundinacea*, is widely used in the gluten-free food market due to its high digestibility and neutral flavor. Arrowroot flour is used in a variety of products, from baby foods to thickening agents for soups and sauces. This product has grown in demand, especially among health-conscious consumers who seek hypoallergenic and easy-to-digest alternatives (Owoeye *et al*., 2021). Despite the promising potential of value-added tuber crops, several challenges remain in the commercialization process. One of the major obstacles is the lack of standardized processing techniques and quality control, which can lead to inconsistencies in product quality. Furthermore, the need for efficient supply chains and adequate infrastructure in rural areas remains a significant hurdle (Hassan *et al*., 2021). To ensure the successful commercialization of underutilized tubers, it is essential to invest in local processing facilities, provide farmers with technical training, and implement quality assurance protocols that guarantee the safety and efficacy of tuber-based products. In addition, improving access to funding and market research will enable small holder farmers and entrepreneurs to better meet consumer demands. The value addition and commercialization of underutilized tuber crops present substantial opportunities for rural communities to diversify their incomes, contribute to global markets, and support the growing demand for healthy, sustainable food products. As the world's population continues to grow and consumers shift toward plant-based, gluten-free, and functional foods, the potential for tuber crops to play a significant role in the global food and nutraceutical industries is immense. With the right investments in research, infrastructure, and processing technologies, underutilized tuber crops can transition from being overlooked agricultural commodities to key ingredients in health-conscious and environmentally sustainable food products (Pushpalatha *et al*., 2023; Flores *et al*., 2003).

7. Future prospects

The future of underutilized tuber crops in pharmaceutical and nutraceutical domains hinges on a multidisciplinary research approach that integrates genomics, metabolomics, biotechnology, and clinical science. Genomic and metabolomic profiling offer powerful tools to unravel the genetic diversity and biochemical pathways responsible for the biosynthesis of valuable secondary metabolites. Such studies not only facilitate the identification of elite genotypes with superior therapeutic traits but also enable the selection of specific cultivars for targeted breeding programs. Advances in biotechnology, including tissue culture, genetic engineering, and molecular marker-assisted selection, present opportunities to enhance the yield, disease resistance, and functional properties of these crops. Furthermore, there is a pressing need to develop standardized pharmacopoeial monographs that define quality control parameters for tuber-derived compounds to ensure safety, efficacy, and reproducibility in both research and commercial applications. Establishing such standards would also support regulatory approval and market acceptance of derived products. Despite promising preclinical evidence, clinical research on underutilized tubers remains limited. Future studies should focus on designing well-structured human trials to validate therapeutic claims, determine optimal dosages, and assess long-term safety. Collaborative efforts among researchers, healthcare professionals, and industry stakeholders will be essential for transforming these nutritionally and pharmacologically rich crops into mainstream health products with global relevance.

8. Conclusion

Underutilized tuber crops represent a largely untapped reservoir of nutritional and therapeutic wealth. Rich in bioactive compounds such as antioxidants, dietary fibers, resistant starches, and phytochemicals with anti-inflammatory, antidiabetic, antimicrobial, and anticancer properties, these crops offer a wide spectrum of health-promoting effects. Their pharmacological potential is further complemented by their ability to support vital physiological functions, including neuroprotection, liver health, metabolic regulation, and immune modulation. These unique attributes position underutilized tubers not just as functional foods, but as valuable candidates in the development of nutraceuticals and plant-based therapeutics. Beyond their biomedical promise, promoting the cultivation and utilization of these crops can play a significant role in enhancing food and nutrition security, especially in marginalized and climate-vulnerable regions. Their adaptability to diverse agroecological conditions, coupled with low input requirements, makes them suitable for sustainable agriculture and rural development. By investing in research, processing innovations, and value addition, and by integrating traditional knowledge with modern science, these crops can be brought into the mainstream. In doing so, they can contribute meaningfully to global efforts aimed at improving public health, diversifying food systems, and building resilient, nutrition-sensitive value chains.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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